

STIRRING BLADE AND STIRRER FOR MOLTEN GLASS

BACKGROUND

Technical Field

(0001)

The present invention relates to a stirring blade for molten glass for uniformly stirring molten glass in a stirring tank, and a stirrer including this stirring blade in the stirring tank.

Description of Related Art

(0002)

In a manufacture of a glass plate, there is a problem that deterioration in quality of a glass product is greatly affected by an existence of a heterogeneous glass in a molten glass. The heterogeneous glass means a phenomenon that glass with different compositions exists in the molten glass, and is different from molten glass around the heterogeneous glass in characteristics such as specific gravity and refractive index. When the heterogeneous glass exists in a glass product after forming and solidification, lines called ream are generated. This causes an optical image to be distorted and transparency and reflectivity to be damaged.

(0003)

Particularly, in a manufacturing field of a glass

substrate for flat panel display (FPD) and an optical glass, generation of the ream causes a trouble to occur in a manufacturing step of a display apparatus, such as a failure in formation of a TFT circuit by irregularities of the ream, in addition to remarkable deterioration of a product quality. Also, in recent years, the glass substrate for FPD gets larger and larger. When the glass substrate gets larger, use amount of glass in each glass product is increased. Therefore, when the glass substrate is molded, with the heterogeneous glass included in the molten glass, the whole of this glass substrate becomes defective, thus remarkably deteriorating the yield of products.

(0004)

Various causes of generating the heterogeneous glass are considered, such as inappropriate blending of glass raw materials, defectiveness of melting conditions, eluting components from a material of a melting tank, and volatilization from a surface of a molten glass. Therefore, in the manufacture of the glass plate, mechanical stirring is generally performed, as a method of preventing the generation of the heterogeneous glass and realizing a homogeneous molten glass.

(0005)

An object of stirring is to make the heterogeneous glass reduced and disappear, which is generated in the

manufacturing step of the glass. Particularly, high degree of homogeneous property of the optical glass and the glass for FPD is required, and therefore the molten glass must be homogenized in the step before solidifying the molten glass in the forming step. Therefore, the heterogeneous glass generated in the melting step and the refining step, or generated in a transfer tube through which the molten glass is transferred, is reduced or disappear by mechanical stirring.

(0006)

Stirring is performed in a cylindrical vessel called a stirring tank or in a flow passage. A stirring blade is disposed within the stirring tank, and by rotating the stirring blade for prescribed number of times, shearing force is added to the molten glass, to thereby stir the molten glass. The molten glass is flown-in from an inflow port in an upper part of the stirring tank, and flows-out from an outflow port in a lower part of the stirring tank while being stirred. Alternately, reversely, the molten glass is flown-in from the inflow port in the lower part of the stirring tank, and flows out from the outflow port in the upper part of the stirring tank while being stirred.

(0007)

When the shearing force is added to the heterogeneous glass in the molten glass, the

heterogeneous glass is sheared, thus making the heterogeneous glass disappear or reduced. The shearing force is generated in a part where a speed difference in fluidity of the molten glass is generated, such as the stirring blade and a wall of the stirring tank. A stirring speed (the number of rotations: rpm) is suitably decided by viscosity (temperature) and a specific gravity of the molten glass, and the molten glass with high viscosity carries out low-speed rotation. For example, stirring is performed, with low-speed rotation of about 10rpm.

(0008)

As a conventional stirring blade for molten glass, so-called crank-type stirring blade, paddle-type stirring blade (for example, see patent document 1), or screw-type stirring blade (for example, see patent document 2), are known.

(0009)

FIG.9 shows an example of the crank-type stirring blade. A stirring blade 110 is disposed inside of a cylindrical stirring tank 101, and by driving the stirring blade 110 to rotate around a rotational axis set on a center axis of the stirring tank 101, molten glass G in the stirring tank 101 is stirred. The stirring blade 110 includes: a rotational shaft 111 positioned on the rotational axis; a vertical bar-like first blade

112 that extends in a vertical direction along the rotational axis at a position apart from the rotational axis in a rotational radial direction, for stirring the molten glass G that exists in an outer peripheral area of the stirring tank 101, by being rotated in the vicinity of an inner wall of the stirring tank 101; and a horizontal bar-like second blade 113 that extends along the rotational radial direction orthogonal to the rotational axis, for stirring the molten glass G that exists in a range from a central part area to an outer peripheral area of the stirring tank 101, by being rotated in the range from the central part area to the outer peripheral area of the stirring tank 101. The rotational shaft 111 is rotated by a motor 118.

(0010)

The stirring tank 101 has inlets/outlets 102 and 103 for the molten glass in the upper part and in the lower part, and in the stirring tank 101, the molten glass G flows-in from the inlet/outlet 102 in the upper part and flows-out from the inlet/outlet 103 in the lower part while being stirred. Alternately, reversely, the molten glass G flows-in from the inlet/outlet 103 in the lower part and flows-out from the inlet/outlet 102 in the upper part while being stirred.

(0011)

(Patent document 1)

Japanese Patent Laid Open Publication No.2001-72426

(Patent document 2)

Japanese Patent Laid Open Publication No.2008-120630

(0012)

Incidentally, in a conventional stirring blade, there is a problem that flow-out of the heterogeneous glass occurs easily, due to insufficient shearing force during stirring. Namely, some of the molten glass in the stirring tank flows-in from the inflow port and flows-out from the outflow port, with almost no shearing force added thereto by stirring.

(0013)

It appears that this is caused by a difference of a peripheral speed between the central part and the outer peripheral part of the stirring blade. For example, in a case of the crank-type stirring blade 110 shown in FIG.9, as shown in a horizontal cross section of FIG.10, peripheral speed R1 in the central part of the rotating stirring blade 110 is small, and peripheral speed R2 of the outer peripheral part is large.

(0014)

Therefore, as shown in a schematic vertical sectional view of FIG.11, the molten glass G is flown into outer peripheral area FB of the stirring tank 101 from the inlet/outlet 102 in the upper part as shown by arrow A. Then, the molten glass is flown-out from the

inlet/outlet 103 while being stirred satisfactorily, with a sufficient shearing force added thereto by the rotation of the vertical bar-like first blade 112 and a horizontal bar-like second blade 113. However, the following phenomenon occurs. Namely, the molten glass G that flows into the central area FA of the stirring tank 101 descends from an upper side to a lower side of the central area FA as it is, as shown by arrow P, with no sufficient shearing force added thereto by stirring, and flows-out from the inlet/outlet 103 in the lower part. Thus, the molten glass that receives no sufficient shearing force in the stirring tank 101 is insufficiently homogenized due to insufficient stirring, thus causing the ream to be generated. The same thing can be said for the paddle-type stirring blade.

(0015)

Therefore, in order to solve the above-described problem, increase of the number of rotations of the stirring blade can be taken into consideration. If the number of rotations of the stirring blade is increased, the shearing force added to the molten glass in the stirring tank can be increased, and a stirring effect can also be increased.

(0016)

However, when the molten glass has high viscosity, the molten glass with high viscosity is sometimes rotated

together with the stirring blade if the number of rotations of the stirring blade is increased. Therefore, increase of the number of rotations is limited.

(0017)

In addition, platinum or a platinum-alloy is used in a material of the stirring tank and the stirring blade, in terms of a heat-resistant property and an anticorrosive property. However, if the number of rotations of the stirring blade is increased, there is a possibility that platinum of the stirring tank and the stirring blade is peeled-off by stirring the molten glass. The phenomenon of peel-off of platinum by the molten glass occurs in a part where the shearing stress is added by stirring the molten glass, and this phenomenon is easily generated if the molten glass has high viscosity. When a foreign matter (platinum foreign matter) such as platinum or a platinum-alloy peeled-off from the stirring tank and the stirring blade is mixed in the molten glass, trouble in a product glass is caused thereby, because the foreign matter is also included in the glass after forming. For this reason also, the number of rotations of the stirring blade can not be increased so much.

(0018)

Therefore, an object of the patent document 2 is to provide the screw-type stirring blade wherein the

molten glass is flown by a rotational force, along a shape of a spiral blade. In this case, there is a problem that an action of shearing the molten glass is weak, because no speed difference is generated in the molten glass, and therefore a stirring effect becomes low, such as making the heterogeneous glass disappear.

SUMMARY OF THE INVENTION

(0019)

In view of the above-described circumstance, an object of the present invention is to provide a stirring blade for molten glass capable of sufficiently stirring an entire body of a molten glass in a stirring tank including a central area of a tank and capable of realizing a homogeneous molten glass even if not increasing the number of rotations, and provide a stirrer for molten glass including this stirring blade.

(0020)

A first aspect of the present invention provides a stirring blade for molten glass disposed inside of a cylindrical stirring tank, for stirring molten glass in the stirring tank by being driven to rotate around a rotational axis set on a center axis of the stirring tank, including:

a rotational shaft positioned on the rotational axis;

a vertical bar-like first blade that extends in a vertical direction along the rotational axis at a position apart from the rotational shaft in a rotational radial direction, for stirring the molten glass that exists in an outer peripheral area of the stirring tank, by being rotated in the vicinity of an inner wall of the stirring tank;

a horizontal bar-like second blade that extends along a rotational radial direction orthogonal to the rotational axis, for stirring the molten glass that exists in a range from a central area to an outer peripheral area of the stirring tank, by being rotated in a range from the central area to the outer peripheral area of the stirring tank; and

a disc-like third blade which is provided on an inner peripheral side of the vertical bar-like first blade and extends in a planar shape in a direction orthogonal to the rotational axis, for guiding the molten glass that exists in the central area of the stirring tank to the outer peripheral area.

(0021)

A second aspect of the present invention provides the stirring blade for molten glass according to the first aspect, wherein a plurality of horizontal bar-like second blades and disc-like third blades are respectively provided at intervals in the rotational

axis direction.

(0022)

A third aspect of the present invention provides the stirring blade for molten glass according to the second aspect, wherein the horizontal bar-like second blade and the disc-like third blade are integrally formed at the same position in the rotational axis direction.

(0023)

A fourth aspect of the present invention provides the stirring blade for molten glass according to any one of the first to third aspects, wherein the disc-like third blade is formed into a disc shape, with the rotational axis as a center.

(0024)

A fifth aspect of the present invention provides the stirring blade for molten glass according to any one of the first to fourth aspects, wherein a protruded fourth blade is provided in the disc-like third blade.

(0025)

A sixth aspect of the present invention provides the stirring blade for molten glass according to any one of the first to fifth aspects, wherein the disc-like third blade is provided in a posture inclined to a surface vertical to the rotational axis.

(0026)

A seventh aspect of the present invention provides

a stirrer for molten glass, wherein the stirring blade according to any one of the claims 1 to 6 is disposed inside of a stirring tank which is disposed, with a center axis directed vertically, having an inflow port disposed on one end side and an outflow port disposed on the other end side in a vertical direction, to thereby allow molten glass to flow in the vertical direction.

(0027)

According to the first aspect of the present invention, the molten glass that exists in the central area of the stirring tank, where insufficient stirring easily occurs due to a small peripheral speed of the stirring blade, can be guided to the outer peripheral area by the disc-like third blade having a guiding action. Therefore, insufficient stirring of the molten glass in the central area can be solved, by the stirring action using the first blade and the second blade in a state in which the molten glass is guided to the outer peripheral area. Accordingly, even if not increasing the number of rotations of the stirring blade, stirring of the molten glass in an entire body of the stirring tank can be accelerated, and homogenizing of the molten glass can be accelerated. As a result, even when the heterogeneous glass is flown into the stirring tank, disappearance and reduction of the heterogeneous glass can be realized by stirring, and also generation of the

phenomenon of peel-off of platinum, being a material of the stirring blade and the stirring tank, can be suppressed, because it is not necessary to increase the number of rotations of the stirring blade.

(0028)

According to the second aspect of the present invention, a plurality of horizontal bar-like second blades and disc-like third blades are provided, respectively at intervals in the rotational axis direction. Therefore, the flow of the molten glass can be made toward the outer peripheral area from the central area in the stirring tank, and stirring of the molten glass can be accelerated.

(0029)

According to the third aspect of the present invention, the horizontal bar-like second blade and the disc-like third blade are integrally formed at the same position in the rotational axis direction. Therefore, rigidity is improved.

(0030)

According to the fourth aspect of the present invention, the disc-like third blade is formed into a disc shape, with the rotational axis of the stirring blade as a center, and there are no corners. Therefore, there is little possibility that the third blade is shaved by the molten glass and is worn.

(0031)

According to the fifth aspect of the present invention, slip between the molten glass and the third blade is prevented by an existence of the protruded fourth blade provided in the third blade, and a centrifugal force caused by the rotation of the third blade can be positively given to the molten glass. Therefore, retention of the molten glass on the third blade can be prevented, and the flow of the molten glass to the outer peripheral area from the central area in the stirring tank can be strengthened, and stirring efficiency can be further increased.

(0032)

According to the sixth aspect of the present invention, the disc-like third blade is provided in an inclined posture. Therefore, the flow along this inclination can be given to the molten glass, and the retention of the molten glass on the third blade can be prevented. Further, by rotation of an inclined surface (disc-like third blade), fluidity in the rotational axis direction can be given to the molten glass, then the stirring efficiency can be further increased, and further homogenization of the molten glass can be realized.

(0033)

According to the seventh aspect of the present

invention, the molten glass is sufficiently stirred by the stirring blade, while the molten glass flows to the lower part from the upper part or from the lower part to the upper part of the stirring tank. Therefore, the homogenization of the molten glass by stirring can be accelerated, and as a result, even when the heterogeneous glass is flown into the stirring tank, the disappearance and the reduction of the heterogeneous glass can be realized by stirring.

Brief Description of the Drawings

FIG.1 is a perspective view showing a structure of a stirrer including stirring blades according to an embodiment of the present invention.

FIG.2 is a side sectional view of this stirrer.

FIG.3 is a side sectional view for explaining a principle of this stirrer.

FIG.4 is a perspective view of the stirring blades according another embodiment of the present invention.

FIG.5 is a side view showing a cross-sectional part of these stirring blades.

FIG.6 is a perspective view of the stirring blades according to further another embodiment of the present invention.

FIG.7A is an upper side view of a part of each stirring blade, and FIG.7B is a side view thereof.

FIG.8 is a view showing modified examples (a) to (e) of a fourth blade of the stirring blades shown in FIG.6 and FIG.7.

FIG.9 is a perspective side view of the stirrer including conventional stirring blades.

FIG.10 is a horizontal sectional view of an essential part of this stirrer.

FIG.11 is a side sectional view for explaining a principle of this stirrer.

Best Mode for Carrying out the Invention

(0034)

Preferred embodiments of the present invention will be described hereunder, with reference to the drawings.

FIG.1 is a perspective view showing a structure of a stirrer including stirring blades, FIG.2 is a side sectional view of this stirrer, and FIG.3 is a side sectional view for describing a principle of this stirrer.

(0035)

As shown in FIG.1 and FIG.2, this stirrer includes:

a cylindrical stirring tank 1 installed, with a center axis L1 directed vertically; and

a stirring blade 10 disposed inside of the stirring tank 1. An inflow port 2 of the molten glass is disposed

in an upper part of the stirring tank 1, an outflow port 3 is disposed in a lower part thereof, and molten glass G flows-in from the inflow port 2 in the upper part, then transfers toward the lower part in the stirring tank 1, and flows-out from the outflow port 3 in the lower part.
(0036)

The stirring blade 10 functions to stir the molten glass G of high viscosity in the stirring tank 1, by being driven to rotate at a low speed around a rotational axis L10 set on a center axis L1 of the stirring tank 1.
(0037)

This stirring blade 10 has a so-called crank-type shape as a basic shape, and includes a rotational shaft 11 positioned on the rotational axis L10; a vertical bar-like first blade 12 extending vertically along the rotational axis L10 at a position apart from the rotational axis L10 in a rotational radial direction, for stirring the molten glass G that exists in an outer peripheral area FB in the stirring tank 1, by being rotated in the vicinity of an inner wall of the stirring tank 1; a horizontal bar-like second blade 13 extending along the rotational radial direction orthogonal to the rotational axis L10, for stirring the molten glass G that exists in a range from a central area FA to an outer peripheral area FB in the stirring tank 1, by being rotated in the range from the central area FA to the outer

peripheral area FB in the stirring tank 1; and a disc-like third blade 14 provided on inner peripheral side of the vertical bar-like first blade 12 so as to be extended in a planar shape in a direction orthogonal to the rotational axis L10, for guiding the molten glass G that exists in the central area FA in the stirring tank 1 to the outer peripheral area FB.

(0038)

At least one or more horizontal bar-like second blades 13 and disc-like third blades 14 are provided respectively at intervals in a direction of the rotational axis L10, and are integrally formed at the same position in the direction of the rotational axis L10. At this time, preferably the number of installation of the disc-like third blades is two or more, and 3 to 5 are further preferable. Further, the disc-like third blades 14 are formed into a disc shape, with the rotational axis L10 as a center, and are fixed to the rotational shaft 11 and the second blade 13 in a posture vertical to the rotational axis L10. Moreover, two vertical bar-like first blades 12 are disposed at a position opposed 180°, and the horizontal bar-like second blades 13 are disposed in a posture vertical to the rotational axis L10, with both ends connected to the two first blades 12.

Note that the first blade 12 and the second blade

13 are formed by a round rod, and a diameter of the round rod of the second blade 13 is set larger than a thickness of a disc-like third blade 14. Then, the disc-like third blade 14 is joined to a central part in a height direction of the round bar that constitutes the second blade 13.

(0039)

As described above, the stirring blade 10 is characterized in that the disc-like third blade 14 is added to a so-called crank-type stirring blade, and by adding the third blade 14, this stirrer is capable of increasing a stirring effect for the molten glass G by transferring the molten glass G in the central area FA, where the stirring effect is hardly obtained when a low-speed rotation is carried out in the crank-type stirring blade, to the outer peripheral area FB in the stirring tank 1.

(0040)

Namely, according to this stirrer, as an action principle is shown in FIG.3, the molten glass G that exists in the central area FA of the stirring tank 1, where insufficient stirring easily occurs due to a small peripheral speed of the stirring blade 10, can be guided to the outer peripheral area FB by the disc-like third blade 14 having a guiding action. Then, by the stirring action of the first blade 12 and the second blade 13 in a state in which the molten glass is guided to the outer

peripheral area FB, insufficient stirring of the molten glass G in the central area FA can be solved. Accordingly, even if not increasing the number of rotations of the stirring blade, stirring of the molten glass in an entire body of the stirring tank can be accelerated, and homogenization of the molten glass can be accelerated. As a result, even when the heterogeneous glass is flown into the stirring tank, disappearance and reduction of the heterogeneous glass can be realized by stirring, and also generation of a peel-off phenomenon of platinum, etc, being a material of the stirring blade and the stirring tank, can be suppressed.

(0041)

For example, as shown by arrow A, in the molten glass G flown into the stirring tank 1 from the inflow port 2 in the upper part, a part of the molten glass G is flown into the central area FA in the stirring tank 1, which is then flown from the central region FA to the outer peripheral region FB as shown by arrow Q, because the disc-like third blade 14 exists in a center part of the stirring blade 10, and is stirred by the first blade 12 and the second blade 13 in the outer peripheral region FB. Accordingly, stirring of the molten glass G in an entire body of the stirring tank 1 can be accelerated, and the homogenization of the molten glass G by stirring can also be accelerated. As a result, even when the

heterogeneous glass is flown into the stirring tank 1, the disappearance or reduction of the heterogeneous glass can be realized by stirring.

(0042)

In addition, in a case of this embodiment, there are provided a plurality of horizontal bar-like second blades 13 and disc-like third blades 14 respectively in the direction of the rotational axis L10 at intervals. Therefore, it is possible to make the flow of the molten glass G toward the outer peripheral area FB from the central area FA in the stirring tank 1, at each place in the axial direction of the stirring tank 1, and also possible to accelerate stirring of the molten glass G. Further, the disc-like third blade 14 is formed into a disc shape, with the rotational axis L10 of the stirring blade 10 as a center and has no corners, and therefore there is little possibility that the third blade 14 is shaved by the molten glass and is worn. Moreover, the horizontal bar-like second blade 13 and the disc-like third blade 14 are integrally formed at the same position in the direction of the rotational axis L10. Therefore, there is a merit that improvement of rigidity of the stirring blade 10 can be realized.

(0043)

In addition, it is also possible to form the third blade 14 into a flat plate shape, such as a polygonal

shape (square or hexagonal shape), other than the disc shape. However, if the third blade 14 is formed into the polygonal shape, there is a possibility that "corner" portions are shaved by the molten glass and are worn, and the shaved portion becomes a foreign matter in the molten glass, resulting in a problem in terms of a quality of products. Accordingly, the polygonal shape is not desirable, and a circular shape is most preferable. Also, an oval shape is also acceptable.

(0044)

Moreover, the above-description shows a case in which the molten glass is flown-in from the upper part and flown-out from the lower part of the stirring tank 1. However, reversed flow may also be acceptable. Namely, it is also possible to use the flow of the molten glass that flows-in from the lower part and flows-out from the upper part. In this case, the inflow port 2 of the upper part becomes an outflow port, and the outflow port 3 of the lower part becomes an inflow port.

(0045)

In addition, as shown in FIG.1 and FIG.2, the aforementioned embodiment shows a case in which the disc-like third blades 14 are provided in a posture vertical to the rotational axis L10. However, disc-like third blades 24 may also be provided in a posture inclined to a surface vertical to the rotational axis L10, like

a stirring blade 20 shown in FIG.4 and FIG.5.

(0046)

Thus, when the disc-like third blades 24 are provided in inclined postures, the flow along inclination of the third blades 24 can be given to the molten glass, and the molten glass G can be prevented from being retained on the third blades 24. In addition, by rotation of the inclined surface (disc-like third blades 24), fluidity can be given to the molten glass G in the direction of the rotational axis L10. Therefore, the stirring efficiency can be further increased, and further homogenization of the molten glass can be realized.

(0047)

In addition, as shown in FIG.1 and FIG.2, the aforementioned embodiment shows a case in which nothing is added to the upper/lower surfaces of the disc-like third blades 14. However, protruded fourth blades 35 may also be provided on plate surfaces of the disc-like third blades 14. In this case, the fourth blades 35 are provided on the plate surfaces on which the molten glass flows (upper surface when the molten glass flows from the upper side, and lower surface when the molten glass flows from the lower side).

(0048)

As shown in FIG.7(a), each fourth blade 35 in this

case is extended radially outward from the outer peripheral surface of the rotational shaft 11, and two fourth blades 35 are provided at a position opposed 180° , with the rotational shaft 11 sandwiched between them, so as to be disposed at intervals of suitable angle θ , (for example, $\theta = 60^\circ$) on the front side of a rotating direction R of the second blade 13. The value of θ is set to be in a range of $30^\circ \leq \theta \leq 90^\circ$. Thus, it is possible to take wider upper surface area of the third blade 14 (area between the second blade 13 and the fourth blade 35) on the front side in the rotating direction of the fourth blades 35, and a scraping effect by the fourth blades 35 can be increased. Note that as shown in FIG.7(b), each fourth blade 35 protrudes higher than the height of an upper half portion of the round bar-like second blade 13 protruded from the upper surface of the third blade 14. Otherwise, the scraping effect by the fourth blades 35 can not be expected.

(0049)

Further, in an example shown in the figure, each fourth blade 35 is formed by a flat plate vertical to the third blade 14, which is inclined so as to have a higher height on the rotation center side and have a lower height toward the outer peripheral side. Note that each fourth blade 35 may also be formed in such a manner as extending to the outer peripheral side from the rotation

center side, with simply the same height, or may also be formed reversely to the example in the figure, in such a manner as being inclined so as to have a lower height on the rotation center side and a higher height toward the outer peripheral side.

(0050)

In addition, as shown in FIG.8, the fourth blade 35 can be variously modified.

(a) shows an example of a case of constituting the fourth blade 35a using a flat plate erected vertically to the third blade 14, (b) shows an example of a case of constituting the fourth blade 35b by a flat plate in a posture inclined backward with respect to the rotating direction R of the stirring blade, (c) shows an example of a case of constituting the fourth blade 35c using the flat plate in a posture inclined frontward with respect to the rotating direction R of the stirring blade, (d) shows an example of a case of constituting the fourth blade 35d using a bar-like member having a cross-sectionally triangular shape, and (e) shows an example of a case of constituting the fourth blade 35d using a bar-like member having a cross-sectionally semi-circle.

(0051)

For example, as shown in the example of (b), when the fourth blade 35d is constituted using the flat plate

in the posture inclined backward with respect to the rotating direction R, the molten glass retained on the third blade 14 can be transferred to the outer peripheral side, while suppressing a scraping resistance small, which is caused by the fourth blade 35b. Accordingly, peel-off prevention effect for the material of the fourth blade 35b can be obtained, compared with a case in which the fourth blade 35a is vertical.

(0052)

Moreover, as shown in the example of (c), when the fourth blade 35c is constituted using the flat plate in the posture inclined frontward with respect to the rotating direction R, slip with respect to the molten glass retained on the third blade 14 can be suppressed, and therefore the scraping effect for the molten glass can be increased, compared with a case in which the fourth blade 35a is vertical.

(0053)

In addition, as shown in examples of (d) and (e), when fourth blades 35d and 35e have the cross-sectionally triangular shape and cross-sectionally semi-circular shape, similarly to the example of (b), the molten glass retained on the third blade 14 can be transferred to the outer peripheral side, while suppressing the scraping resistance small, which is caused by the fourth blades 35d and 35e. Accordingly, the peel-off prevention

effect of the material of the fourth blades 35d and 35e can be obtained, compared with a case in which the fourth blade 35a is vertical.

(0054)

Thus, when the fourth blades 35 (35a to 35e) are provided on the flat plate of the third blades 14, slip between the molten glass and the third blade 14 can be prevented by an existence of the fourth blades 35. Accordingly, a centrifugal force caused by rotation of the third blades 14 can be positively applied to the molten glass, and the molten glass can be prevented from being retained on the third blades 14. As a result, the flow of the molten glass to the outer peripheral area FB from the central area FA in the stirring tank 1 can be strengthened, and further the stirring effect can be increased.

(Examples)

(0055)

Next, specific examples will be described.

(0056)

The viscosity, temperature, and flow rate of the molten glass, being a target, are approximately as follows.

Temperature: 1450°C to 1550°C

Viscosity: 900 to 2000 poise (90 to 200Pa·s)

Flow rate: 3cm/min to 6cm/min

(0057)

Also, the composition of the molten glass is shown in table 1.

(0058)

(Table 1)

Composition of Molten glass (mol%)

SiO ₂	50~70
Al ₂ O ₃	5~15
B ₂ O ₃	5~15
MgO	0~3
CaO	3~10
SrO	1~3
BaO	0~5
Na ₂ O	0~1
K ₂ O	0~1
As ₂ O ₃	0~1
Sb ₂ O ₃	0~1
SnO ₂	0~2
Fe ₂ O ₃	0~2
ZrO ₂	0~2

(0059)

Platinum and a platinum alloy are given as materials of the stirring tank and the stirring blade. As an example of the platinum alloy, "platinum-rhodium alloy" and "platinum-iridium alloy" can be given, when used in the molten glass of a high temperature range. Also, when used in the molten glass of a low temperature range, "platinum-palladium alloy", "platinum-gold alloy", and

"platinum-nickel alloy" can be given.

(0060)

Further, dimension of the stirring blade depends on an inner diameter of the stirring tank and an average passage amount (average stay time) of the molten glass. Even if the dimension of the stirring tank is increased without restriction to grow in size, there is a restriction in aspects of strength and efficiency. Therefore, normally a plurality of stirring tanks are installed, and for example, these stirring tanks are used by being connected in series by flow passages. At that time, when the molten glass is transferred from the upper side to the lower side in the stirring tank of the front stage, the flow passages are connected so as to transfer the molten glass from the lower side to the upper side in the stirring tank of the rear stage.

(0061)

Optimum dimensions of the stirring tank and the stirring blades are decided as follows.

First, regarding a clearance between the stirring blades and the stirring tank, generally a shearing effect is increased if the clearance (gap) between the stirring blades and an inner wall surface of the stirring tank is small. As actual dimensions of the clearance, 10mm to 30mm are desirably ensured, and most desirably 15mm to 20mm are set.

(0062)

In addition, as the dimension of the stirring tank, the inner diameter is desirably set to be 500mm or less, and is most desirably set to be 300mm to 400mm. Depth of the stirring tank is restricted from the aspect of strength, because the pressure of the molten glass is added to the lower part of the stirring tank (if the thickness of platinum, being the member of the stirring tank, is increased, the depth of the stirring tank is also increased). Actually, the depth of the stirring tank is desirably set to be 500mm to 1500mm, and most desirably set to be 600mm to 1000mm.

(0063)

Further, regarding the dimension of the disc-like third blade of the stirring blades, when the outer diameter is too large, a dead space (space where no molten glass is stirred) is generated between upper and lower discs. Also, when the diameter of the disc-like blade is too small, the effect of transferring the molten glass from the central area to the outer peripheral area of the stirring tank, which is an object of the present invention, can not be obtained. Therefore, when the inner diameter of the stirring tank is set to be 1.0, the outer diameter of the third blade is desirably set to be 0.2 to 0.6.

(0064)

After experiment was performed, with the aforementioned conditions satisfied, it was found that when the stirring blades of the present invention were used, generation of ream could be suppressed without increasing the number of rotations but rather decreasing the number of rotations of the stirring blades. Namely, when the stirring blades of the present invention were used, generation of ream could be suppressed, even when the number of rotations was decreased by 30% of the number of rotations required for homogenization of the molten glass by conventional stirring blades. This reveals the fact that by the stirring blades of the present invention, a sufficient shearing force can be added to the entire body of the molten glass in the stirring tank including the molten glass of the central area in the stirring tank, to thereby make the heterogeneous glass disappear. Further, a peel-off phenomenon of platinum, etc, was not observed, because the number of rotations of the stirring blades could be reduced.

(0065)

The stirring blades of the present invention as described above could be used in all kinds of glasses such as a glass substrate, a glass substrate for an FPD glass substrate, an optical glass, a building glass, and a bottle glass. Also, a supply device of the molten glass using the stirring blades of the present invention is

suitable for being used in a down-draw type forming device, but can also be applied to the other type forming device.

What is claimed is:

1. A stirring blade for molten glass disposed inside of a cylindrical stirring tank, for stirring molten glass in the stirring tank by being driven to rotate around a rotational axis set on a center axis of the stirring tank, comprising:

a rotational shaft positioned on the rotational axis;

a vertical bar-like first blade that extends in a vertical direction along the rotational axis at a position apart from the rotational shaft in a rotational radial direction, for stirring the molten glass that exists in an outer peripheral area of the stirring tank, by being rotated in the vicinity of an inner wall of the stirring tank;

a horizontal bar-like second blade that extends along a rotational radial direction orthogonal to the rotational axis, for stirring the molten glass that exists in a range from a central area to an outer peripheral area of the stirring tank, by being rotated in a range from the central area to the outer peripheral area of the stirring tank; and

a disc-like third blade which is provided on an inner peripheral side of the vertical bar-like first blade and extends in a planar shape in a direction orthogonal to the rotational axis, for guiding the molten

glass that exists in the central area of the stirring tank to the outer peripheral area.

2. The stirring blade for molten glass according to claim 1, wherein at least one or more horizontal bar-like second blades and disc-like third blades are respectively provided at intervals in the rotational axis direction.

3. The stirring blade for molten glass according to claim 2, wherein the horizontal bar-like second blade and the disc-like third blade are integrally formed at the same position in the rotational axis direction.

4. The stirring blade for molten glass according to any one of claims 1 to 3, wherein the disc-like third blade is formed into a disc shape, with the rotational axis as a center.

5. The stirring blade for molten glass according to any one of claims 1 to 4, wherein a protruded fourth blade is provided in the disc-like third blade.

6. The stirring blade for molten glass according to any one of claims 1 to 5, wherein the disc-like third blade is provided in a posture inclined to a surface

vertical to the rotational axis.

7. A stirrer for molten glass, wherein the stirring blade according to any one of the claims 1 to 6 is disposed inside of a stirring tank which is disposed, with a center axis directed vertically, having an inflow port disposed on one end side and an outflow port disposed on the other end side in a vertical direction, to thereby allow molten glass to flow in the vertical direction.